NEW METHODS OF FISH STOCK ASSESSMENT

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1. Multispecies Surplus Production Model

This is a multivariate version of single species surplus production model. Here, the annual surplus production (ASP) is calculated for each stock as:

$$\text{ASP}_{j,t} = B_{j,t+1} - B_{j,t} + \delta_j C_{j,t}$$

where $B_{j,t}$ is the estimated "adult" biomass of stock *j* at the beginning of year *t*, $C_{j,t}$ the catch of stock *j* during year *t*, and δ_j is a stock-specific correction factor that accounts for growth and mortality that would have taken place between the time the catch was taken and the beginning of year *t+1*. Assuming an additive error structure for annual surplus production, the estimating equations take the form of a multiple linear regression for the Graham-Schaefer model and a non-linear regression for the Pella-Tomlinson model (Quinn and Deriso, 1999):

Graham-Schaefer : $ASP_t = \alpha\, \overline{B}_t + \beta\, \overline{B}_t^{\,2} + \varepsilon_t$

Pella-Tomlinson : $ASP_t = \alpha\, \overline{B}_t + \beta\, \overline{B}_t^{\,\nu} + \varepsilon_t$

where α, β, and ν are model parameters and εt are model residuals that are assumed to be normally distributed.

2. Multispecies Virtual Population Analysis (MSVPA) Model

Multispecies virtual population analysis is an extension of the VPA model for simultaneous analysis of data for more than one species that incorporates the predator stomach content data into the virtual population model. In MSPVA through a recursive algorithm the fishing mortality at different age, recruitment, stock size, suitability coefficients and predation mortality are calculated based on catch-at-age data, predator ration and predator diet information. MSVPA allows the estimation of vital population rates used in the management of fishery resources. An additional advantage of the model is the estimation of the predation mortalities produced by predators on preys species and the annual consumption of prey by predators. The MSVPA input data includes the catch-at-age data, percent of maturity-at-age, weight-at-age, terminal fishing mortalities, predator stomach content data and residual mortalities.

3. Dynamic Multispecies Models

These models consider the functional relationships among individual species in a fished system. They build upon single-species theory to understand the dynamics of multispecies fisheries. These models account for interactions among selected species (often exploited fish species) but do not address the ecosystem as a whole. Dynamic multispecies models consider predator–prey interactions and evaluate the interactions between a subset of the species in the ecosystem. They do not model competitive interactions explicitly, but often include constraints such as conservation of total system biomass, or constant input of food from outside the model, which result in changes in abundance of one species indirectly affecting the abundance of species with which it shares prey. Eg: virtual population analysis (VPA) models allowing for cannibalism, multispecies VPA (MSVPA) and statistical assessment models (SAM; single-species with predation).

4. OSMOSE Model

OSMOSE is a multispecies/single species model for fish species. The model assumes predation based on spatial co-occurrence and size and represents fish grouped into school characterized by their size, weight, age, taxonomy and geographical location. The processes considered in the fish life cycle are growth, explicit predation, natural and starvation mortalities, reproduction, migration and a fishing mortality distinct for each species. OSMOSE has been first applied to the Benguela upwelling ecosystem for which 12 fish species have been specified, from small pelagic fish to large demersal species The model needs basic parameters that are often available for a wide range of species. On output, a variety of size-based and species-based ecological indicators can be simulated and converted to in situ survey and catch data at the species level and community level. The model can be calibrated to observe biomass dynamics.

5. Atlantis

Atlantis is an ecosystem model that considers all the components of marine ecosystems namely biophysical, economic and social. It is a deterministic biogeochemical ecosystem model with its overall structure based around the Management Strategy Evaluation (MSE) approach. There are sub-models (or module) for each of the major steps in the adaptive management cycle. deterministic biophysical sub-model is at the core of the model, coarsely spatially-resolved in three dimensions, which tracks nutrient flows through the main biological groups in the system. The primary ecological processes considered in the model are consumption, production, waste production, migration, predation, recruitment, habitat dependency, and mortality. The trophic resolution is typically at the functional group level. The physical environment is represented via a set of polygons matched to the major geographical and bioregional features of the simulated marine system and biological model components are replicated in each depth layer of each of these polygons.

Atlantis also includes a detailed exploitation sub-model. This model is focused on the dynamics of fishing fleets and also deals with the impact of pollution, coastal development, environmental (e.g. climate) change. It allows for multiple fleets, each with its own characteristics of gear selectivity, habitat association, targeting, effort allocation and management structures. It includes explicit handling of economics, compliance decisions, exploratory fishing and other complicated real world concerns.

The sampling and assessment sub-model in Atlantis is designed to generate sector dependent and independent data with realistic levels of uncertainty measurements. These simulated data are based on the outputs from the biophysical and exploitation sub-models, using with a user-specified monitoring scheme. The data are then fed into the same assessment models used in the real world, and the output of these is input to a management sub-model. This last sub-model is a set of decision rules and management actions, which can be drawn from an extensive list of fishery management instruments such as gear restrictions, days at sea, quotas, spatial and temporal zoning, discarding restrictions, size limits, bycatch mitigation, and biomass reference points.

6. Size Spectrum Model

Charles Elton introduced the “pyramid of numbers” in the late 1920s, but this remarkable insight into body-size dependent patterns in natural communities lay fallow until the theory of the biomass size spectrum was introduced by aquatic ecologists in the mid-1960s. They noticed that the summed biomass concentration of individual aquatic organisms was roughly constant across equal logarithmic intervals of body size from bacteria to the largest predators. These observations formed the basis for a theory of aquatic ecosystems, based on the body size of individual organisms, that revealed new insights into constraints on the structure of biological communities. Size spectrum is the distribution of biomass/abundance as a function of individual mass or size. The shape of this function resembles a power function and biomass size spectrums are represented using power functions. Spatial and temporal variability in the community structure can be observed in the shape of biomass size spectra.

7. Stock Synthesis

In the history of fish stock assessment two different approaches dominated. One using time series of an indicator of stock abundance (standardized catch rate as a proxy for stock abundance) along with time series of fish catch (Schaefer, 1954). These models provide inference about current and target fish stock abundance and the maximum sustainable yield. The second approach depend on a time series of detailed fish catch-at-age data in order to reconstruct the virtual abundance of each annual cohort that had been fished (Pope, 1972 – Virtual Population Analysis, VPA). In the last two decades there has been development of a third approach known as Integrated Analysis (IA) that takes a more inclusive approach to modeling fish population dynamics utilizing a wide range of available data. Stock Synthesis (SS), implementation of IA, began during the early 1980s. Synthesis is a term used for development of a new product that is more than an blend of its dissimilar parts. In fish stock assessments, different kinds of data can provide complementary information about the fish stock, but one source may not be sufficient in itself to provide a complete picture of the stock’s abundance and the impact of fishing on the stock. Stock Synthesis inherently blends the population estimation paradigm of VPA with the population productivity paradigm of biomass dynamics models. The observations that can be included in SS are CPUE, effort, survey abundance, discards, length, age, weight composition data and tag-recapture data. It has capability to use time series of environmental and ecosystem factors to influence the poplation dynamics and observation processes over time. Three stages of SS assessment approach are – initial development from northern anchovies (basic concept), re-development as a generalized model for the west coast groundfish and development of the computer code in ADMB (Automatic Differentiation Model Builder).